

Integration Scenarios for Personal Satellite Communications

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ABSTRACT

Personal satellite communications provides the missing link to enable truly global personal communications services (PCS). PCS (i.e., wireless communications) is growing rapidly in major population centers, while the needs of the rural, isolated users are still not being met. Satellite interconnection into the terrestrial systems provides this access while augmenting the existing systems with a seamless network enabling access for all users. This paper details efforts currently underway to integrate satellites into the future planned telecommunications networks and discusses the issues currently being addressed. Topics presented include the benefits of a hybrid (satellite/terrestrial) approach, networking issues, and design, implementation and operational issues.

INTRODUCTION

The 90s and beyond will be an era of explosive growth in the demand for personal information exchange. This includes such fields as voice communications, data communications, information services, position location services, and interactive communications to name but a few. Today's terrestrial networks are well on their way to supporting these services with the advent of universal personal/portable communications. The ultimate version of terrestrial-based PCS would allow a customer to go wherever there were radio ports -- probably in areas with fairly dense populations -- and place and receive calls while moving freely throughout an extended area. Satellite interconnection into these terrestrial systems could provide a complementary service by providing access for rural, isolated users while augmenting the existing

systems with a seamless network providing access for all users.

BENEFITS OF A HYBRID (SATELLITE/TERRESTRIAL) APPROACH

The addition of satellites to terrestrial wireless networks for universal portable communications can be beneficial in many areas. These include increased coverage, capacity expansion, early introduction of new services, unique and enhanced services, improved network management, and system backup and restoration. These are summarized briefly below.

Increased Coverage

Terrestrial systems are necessarily limited in the geographic areas they can cover. This limitation is based on physical situations (such as coverage over rough terrain or oceans) as well as economic limitations (areas where traffic density does not warrant the cost of providing conventional terrestrial coverage). Mobile satellite service can be used to enhance the geographic coverage of the terrestrial system by seamlessly bridging the geographic gaps between terrestrial wireless service areas. This would enable service providers to provide enhanced roaming to either sparsely populated areas or on a regional or global basis.

Capacity Expansion

A hybrid terrestrial/satellite system could make use of the mobile satellite system capacity to relieve peak time congestion on terrestrial systems thereby reducing capitalization requirements. This would be an augmentation terrestrial service which would improve the coverage of terrestrial systems and increase their availability in

areas where path diversity could improve service

Early Service Introduction

New services could be made available initially from a satellite link and later, as the terrestrial infrastructure becomes available, transition to the terrestrial systems. This may be particularly useful in developing countries without an existing terrestrial infrastructure. Revenue producing services could be offered well in advance of cable deployment.

Unique and Enhanced Services

The incorporation of satellites into a terrestrial wireless network could enhance existing services as well as add service features unique to satellite operations. Existing services such as nationwide roaming could now include worldwide roaming. An example of a new service which could be offered (with the use of the intelligent network) would be information services (such as Internet Bulletin Boards) accessed directly from the satellite. This would enable subscribers of this services to use bulletin boards while in transit on an airplane or ship.

Improved Network Management

Satellites could improve the substantial network management tasks of a terrestrial communications system. This is based on the large coverage area the satellite supports. With this more global view, network management tasks such as subscriber location could be enhanced.

System Backup and Restoral

Another role satellites could play in a hybrid network is as a backup network for emergency or other temporary situations. This is a way to quickly provide additional capacity for a short time period. It may be neither timely nor economical to bring in temporary wireline networks whereas the satellite resource would be available immediately. This allows for added reliability through system redundancy.

It is important to note that the satellite would not have system backup and restoral as its' primary function. This would most likely be

unfeasible economically as well as a less than optimal use of system resources. Rather, the primary function of the satellite could be any of the aforementioned areas (e.g., increased coverage, enhanced services, improved network management, etc.). In the event of an emergency, the satellite function would change for the duration of the emergency situation and its' primary role would become that of system backup and restoral. This may necessitate reduced service for users for the temporary period of the emergency.

NETWORKING ISSUES

The biggest challenge in providing personal satellite communications is that of networking the various, and disparate, systems together so that the interconnection is transparent to the users. The terrestrial network is well established, so the aim must be to integrate the satellite system into the existing (and planned) terrestrial infrastructure. Firstly, the satellite network architecture must be designed including orbit determination, satellite payloads, type of coverage (e.g. regional vs. global), and frequency bands. This will be discussed in the next section. This network must then be integrated with the terrestrial network and the question arises as to the optimal level of network integration. Following this, network management and control issues must be addressed such as registration, call initiation and delivery, intersystem roaming, and handoff (if necessary). System management issues, including resource allocation, are critical as satellite capacity is a limited resource. The type of multiple access technique chosen is another important element in providing universal portable communications given the need to efficiently allocate a scarce resource (spectrum) to the large number of planned users. Each of these is detailed in the following.

Level of Integration

Ideally the networks would be integrated at the system level, with common handsets, radio interfaces, multiple access techniques, etc. for the satellite and terrestrial networks. In this ideal scenario, the use of different networks for call completion should be

completely transparent to the user. This may prove to be economically or technically infeasible for the near term, thus other options are being investigated. Satellites could play a complementary role in the network with the emphasis on using satellites for network extension (i.e., increased coverage and capacity expansion) as well as emergency and backup services. A second option would be to use satellites in a strictly supportive role as adding additional channels to cellular.

Intersystem Call Processing

In current day US cellular systems, seamless roaming requires that incoming calls for a roaming mobile be forwarded, or "delivered" from the mobile's home system to the system on which it is currently operating. The call delivery system relies on the mobile's manual or autonomous registration upon entering a "foreign" system. Integration of mobile satellite service into the terrestrial network creates additional complexity for call delivery. The first issue is user location determination (that is, locating users) via the satellite. This could be used solely when users are outside terrestrial coverage, or when the user is within terrestrial coverage but wishes to take advantage of the large "cells" available from the satellite. In the latter case, the satellite network could determine which terrestrial cell is appropriate for this call and forward this information to the terrestrial network. It is assumed that most hybrid (satellite/cellular) mobiles will use the terrestrial network as their home system. Thus, if a mobile initiates a call on a terrestrial network, and is solely registered on that (terrestrial) system, and subsequently the call is handed-off to a satellite system, the original system will have to be notified (via satellite) of the user's current location.

As an example of the previously discussed process, let's examine a call placed from rural California to Los Angeles, California by a user whose home location register is in London. The call goes from rural California to London (in order to access the caller's home location register) and then back to California. This non-optimal path is

sometimes referred to as the "tromboning effect". This situation exists today with terrestrial-only systems, but could be exaggerated by the addition of a space-based network. A solution to this is to use specialized numbers for mobile phones and make extensive use of intelligent network capabilities. This would allow for more efficient call routing and may eliminate the so-called "tromboning effect".

Intersystem Handover

The effectiveness and reliability of intersystem handovers is a key aspect in satellite/terrestrial integration. Handovers are used extensively in current day terrestrial mobile systems for switching between cells as well as for switching between Mobile Switching Centers (MSC in Europe, MISO in the US). Handovers are also planned to be an important element of the planned terrestrial personal communications systems. In fact, as cell sizes continue to decrease, handover frequency may increase (depending on the velocity of the user). In satellite/terrestrial systems, handover may occur between two spots belonging to the same satellite, between adjacent satellites (in the case of a multi-satellite system) or between terrestrial cells and satellite cells. It is the latter case of inter-system handoff which is explored here. A crucial point in the assessment of the procedure is the role played by the user terminal in making handover decisions vs. the role played by the network.

There are a number of possibilities for handover strategies including: network controlled handover (current analog systems), mobile assisted handover (GSM), and mobile controlled handover (future systems). Handoff decisions could be made in various segments of the system. One approach is to use network-layer integration with its associated increase in network intelligence to allow for lower user terminal complexity. This approach depends heavily on the network elements (i.e. the satellite ground stations, the mobile station center, the public land mobile networks) and on the interoperability between them. This interconnection could prove to be rather complex and difficult to coordinate across

international borders. Based on the assumption of the complexity of architecture-level integration, another approach would be to provide service-level integration which may be more practical, more cost effective and more manageable.

Resource Allocation

Management of such complex, interoperable systems depends on the ability to allocate system resources efficiently. The number of space-based channels is necessarily small, particularly when compared to the capacity available on the ground. Thus, channel selection (satellite vs. terrestrial) cannot be based purely on signal quality as doing so would quickly use up the satellite resource (as satellite signal quality will most likely be better than terrestrial). Thus we need a network based strategy. The approach taken, for the most part, is to use terrestrial channels as a first choice, use satellite channels outside terrestrial coverage areas, and use satellite channels for overflow from terrestrial. To accomplish this, some percentage of channels must be allocated specifically for overflow, with the rest of the channels being used for areas where satellites are the only coverage option. Dynamic channel allocation looks to be a good strategy for both the terrestrial and satellite channels. Many simulations are currently being run to investigate the performance tradeoffs for various network based strategies.

Intersystem Network Architecture

The satellite network contains elements on the ground which need to be integrated into the terrestrial systems (both wired and wireless) regardless of what level of intersystem integration is chosen. An example of this would be if a caller on a mobile unit wishes to place a call to a fixed (wired) user. If the mobile user is on a terrestrial mobile system, e.g. cellular, the call goes through the Mobile Switching Center which has links into the public switched networks. The satellite network needs to allow this same interconnection capability. This would occur through the satellite hub station, which would need to provide connections to the public switched networks, as well as to cellular networks if

in-progress call hand-offs are supported. This raises a network architecture question of how to integrate the terrestrial based elements of the satellite network with the existing (and planned) terrestrial infrastructure. Areas which need to be researched include the number of hub stations, the capabilities they provide, and the level at which they are integrated with terrestrial.

Multiple Access Techniques

Both terrestrial and satellite systems have the need for multiple users to access the system simultaneously. Some multiple access techniques are optimized for satellites while other favor cellular systems. A fully integrated system would use the same technique for both systems, but this may not be an optimal system solution (for technical and economic reasons).

The current analog system in use in the US, AMPS (Advanced Mobile Phone Service), uses FDMA. As more and more digital systems come into existence, the decision as to which multiple access technique to use becomes an important one. The US first decided upon a TDMA standard, but now it appears that CDMA is gaining in popularity. There are many simulation results available which point to the benefits of CDMA over other techniques. But even this is not clear cut given the many different "flavors" of CDMA. Other, less popular multiple access techniques, include FDMA, Spread Aloft, and PRMA.

DESIGN, IMPLEMENTATION AND OPERATIONAL ISSUES

Satellite Network Design

A major question in the current environment is the choice of orbits for the satellite component of the network. LEOs can provide for better global coverage while GEOs work for regional (e.g. CONUS) coverage. LEOs and MEOs look very interesting for communications with handheld units while GEOs may be an attractive alternative for vehicular communications. LEOs and MEOs can provide both voice and data service; while, GEOs may be better suited for data-only

applications due to the 280 msec delay factor.

Additionally, one must determine the configuration of the satellite itself. Each satellite could have extensive on-board processing (potentially even with databases) or could function as a strictly bent-pipe system. Intersatellite links allow efficient networking within the satellite network while adding networking complexity to the system as a whole.

Communicating frequencies are another important element of the satellite network. The lower frequencies (< 1 GHz) are usually discarded due to limited bandwidth, and the higher frequencies (> 40 GHz) are usually discarded due to technological challenges. The most oft discussed frequencies are L-, C-, S-, Ku-, and Ka-bands. C-band is used for terrestrial microwave and Ku-band is used for cable stations (i.e., TV broadcast via satellite) but this may be changing due to the influx of fiber optic cables in the terrestrial networks. L- and S-bands are being suggested as candidate frequencies for LEOs and MEOs, all three are being suggested (and tested) for GEO and HEO, and Ka-band is being suggested for aeronautical communications and intersatellite links.

Implementation and Operational Issues

In order for the previously mentioned frequencies to be used for these new service, international regulatory bodies must allocate them accordingly. There are many different regulatory agencies involved in this process (e.g. the FCC in the US, CCIR internationally, ITU, World Administrative Radio Conference (WARC), etc.) and all must agree at some level if the service is to be truly universal. Similar frequency allocations for terrestrial and satellite systems could greatly simplify handset design. Many of these issues are already under consideration (particularly for first generation systems) but much work still remains.

Adding satellites into current terrestrial systems also adds complexity to billing systems. These systems will have to share

information between them to enable accurate billing to occur. In addition, some elements of this information sharing must happen in real-time to enable effective security and authentication. This real-time element could prove difficult for GEO-based systems due to the inherent time delays involved. Nevertheless, it is a crucial issue which must be worked.

CONCLUSIONS

In summary, the field of integrated satellite/terrestrial networks for personal and mobile communications is still in its infancy. Substantial work remains to be done to make this new hybrid network a reality. Sessions such as this one play a crucial role in furthering our knowledge of personal satellite communications advanced technologies and techniques.

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